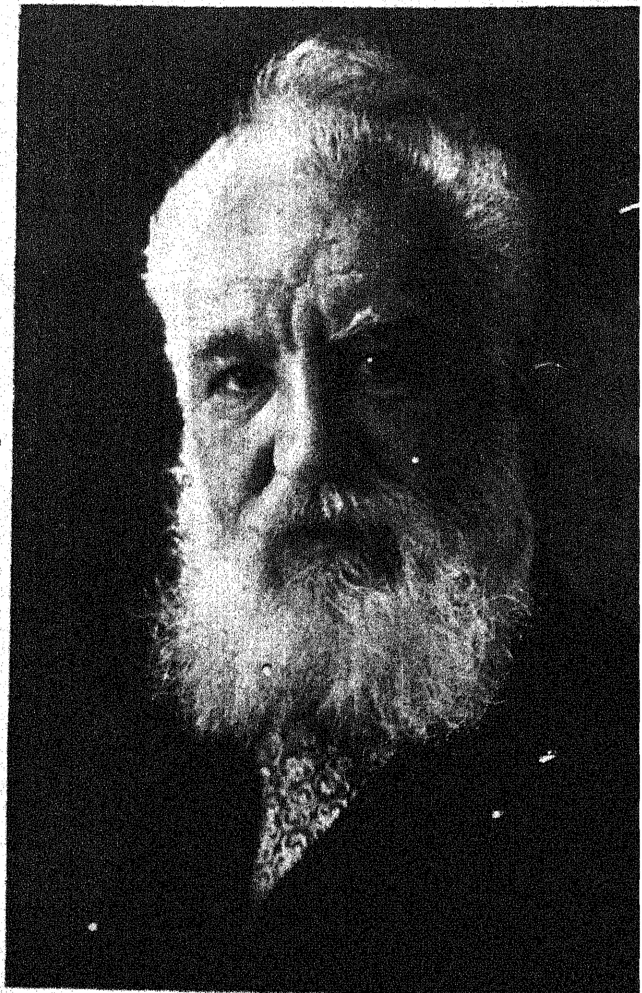

Photo: Topica

ALEXANDER GRAHAM BELL
(1847–1922)

Rambles in Science

TELEPHONES AND GRAMOPHONES

BY

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BLACKIE AND SON LIMITED
50 OLD BAILEY, LONDON; GLASGOW, BOMBAY
1925

Printed in Great Britain by
Blackie & Son, Limited, Glasgow

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TELEPHONES AND GRAMOPHONES

CHAPTER I

About Sound

You know that both the telephone and the gramophone have to do with sound. The *phone* forming the end of each word is from the Greek *phōnē*, which means sound. Several words in common use commence with *tele*. There are telephone, telegraph, telescope, and others. *Tele* is from the Greek *tēle*, meaning at a distance. A telephone means sound at a distance, a telegraph means writing at a distance, and a telescope refers to seeing at a distance.

If we knew nothing whatever about sound, it would not be difficult to discover what produces it. Let us take a gong out into the open where we can make plenty of noise. We beat it with a gong-stick, and it produces plenty of sound. How does it make this sound?

If you touch the gong, you feel it is vibrating. The

particles of which it is made are moving rapidly to and fro. When we wish a drum to produce sound, we strike it with a drum-stick, and the stretched membrane of the drum vibrates. In a bell the metal tongue strikes the gong of the bell, and the bell-vibrates.

When we play a piano, we depress the keys which move some levers and cause little hammers to strike the stretched wires, and they vibrate.

You can feel that the different things are vibrating by touching them lightly. If you press your fingers firmly against them, you damp out the sound and the vibrations cease; there is silence again.

We do not strike a violin to cause it to produce sound, but we make its strings vibrate by drawing a bow across them. In the banjo we pluck the strings to make them vibrate, and in a wind instrument we cause a column of air to vibrate. You have no difficulty in realizing that sound is produced by vibrations.

It is not difficult to picture these vibrating bodies producing waves in the surrounding ocean of air.

A favourite picture with the present writer is that of a boy making waves in a pond of water. We picture the boy having in his hands a pole to the end of which there is fastened a round float. When the boy moves this up and down on the surface of the water, he produces waves which travel across the surface to the edge of the pond.

The boy is causing the float to vibrate at a much

slower rate than the particles of the gong vibrated, but you can picture the gong producing waves in the surrounding ocean of air.

You know that we move about in this air ocean, and that we cannot live out of it. The air forms a great blanket or envelope around the earth, and beyond a certain distance from the earth there is no air.

When we climb a high mountain, we are getting out of the thickest part of the blanket; the air is thinner on the top of the mountain and we feel cold.

The men of the Mount Everest Expedition found it difficult to breathe when they got near the summit of the mountain.

We can swim about, in this air ocean, in balloons, airships, and aeroplanes; but we must be careful not to go too high or we meet with difficulties. Consciousness and life seem to become impossible in the thinner air.

Let us have another look at the picture of the boy in the pond. If he makes large movements of the float, he produces large waves. If we strike our gong hard and cause its particles to make comparatively large movements, we make large waves in the air. We make a loud noise. The loudness depends upon the height of the waves. We may make these waves so vigorous that they hurt our ears. We feel inclined to hold our ears shut when a very loud noise reaches us.

The air-waves beat upon the drums of our ears,

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The air-waves beat upon the drums of our ears,

and the vibrations cause sensations to be telegraphed to the brain.

The great variety of waves which can be made in the air is very remarkable. When an orchestra is playing, you can easily recognize the different instruments which are producing the waves, although these waves are all reaching you at the same time.

Another thing we observe about the boy in the pond is that he can make a great variety of waves. He may make waves with long distances between their crests; we call these *long* waves. Or if he moves the float at a quick rate he produces a series of very *short* waves; they follow close on one another, with only a very short distance between the crests.

The low notes of the piano are produced by the longest and heaviest wires, which move more slowly than the others and produce longer waves.

The high notes in the treble are produced by shorter wires tightly stretched which vibrate much more quickly and set up very short waves. You can realize that what we call the pitch of the note is dependent upon the rate at which the air-waves follow one another. Slow vibrations give a low pitch. Rapid vibrations give a high pitch.

If we use large tuning-forks (fig. 1) to produce the air-waves, we may have one making 400 waves per second, and others making 500, 600, and 800 waves per second. Each of these rates produces a distinct sensation, and with a little practice you may easily tell which fork is sounding. If a fork is producing

400 waves per second, then its prongs must be vibrating 400 times per second. The wire producing the middle C of the piano vibrates about 500 times per second.

We have seen that vibrating bodies produce waves in the air, but the waves may be produced in other things as well as air.

We may ring a bell under water and at some distance place an ear-trumpet in the water, and we

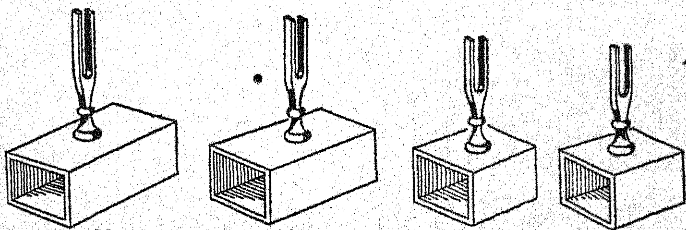


Fig. 1

hear the sound of the bell. Indeed, we can hear the sound much better through the water than through the air. If we use a solid body to convey the vibrations, we find that it acts even better than the water.

If the trunk of some great tree is lying on the ground, we may hear the scratching of a pin right through the whole length of the tree.

If someone scratches the tree at the one end, an ear touching the tree at the other end can hear the sound very distinctly, though a third person, standing quite close to the one making the noise, hears no

sound. The solid tree retains the sound which would otherwise spread out through the air.

You may make a very simple and pleasing experiment in the following manner. Take a metal spoon and tie a long thread to its stem, so that you may hang it in this fashion (fig. 2). Wind the end of each thread round a finger and close both your ears with these two fingers. Then let the spoon knock against the back of a chair or the edge of a wooden table, and you will be surprised at the loudness of the sound produced in your ears. It is like an organ playing.

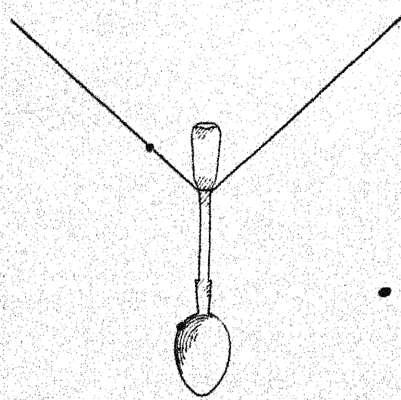


Fig. 2

Fig. 3.—A String Telephone

CHAPTER II

More About Sound

We have seen that a thread or string will convey sound better than the air. There is a very old experiment which proves this.

The apparatus is very simple, consisting of two short cardboard tubes each having a piece of parchment closing one end, and the two parchments being connected together by a thread or string as shown in fig. 3.

We call the round pieces of parchment diaphragms. They might be made of a thin sheet of wood or metal, and we could still describe them as diaphragms.

The apparatus just described is called a string telephone, because it conveys sound to a distance. When two people stand at a distance from one another, holding the instruments so that the string is taut, it is wonderful how even a whisper may be heard.

What happens is this. The air-waves, produced by the speaker, strike the diaphragm in the one instrument and the vibrations are conveyed by the string to the second diaphragm, which imitates the movements of the first, just as a cork would imitate the movements of the float in our picture of the boy and the pond. When the second diaphragm vibrates, it produces air-waves which, falling upon the listener's ear, produce the same sounds as the speaker is making at the other end of the string.

Many years ago I saw a telephone of this kind in practical use in some large engineering works. The diaphragms were made of metal, and they were connected by a stretched wire. They acted very well, and over a considerable distance.

It is evident that the connecting string or wire must not be very long, as it must be stretched tightly and in a straight line.

In the case of the electric telephone it is not sound which travels, it is an electric current.

Although the electric telephone was not invented

till 1876, it was predicted twenty years before that time. In 1854 a French writer suggested an electric telephone, and people regarded it as a fanciful dream. Here is what this French writer said:

"I have asked myself whether speech itself may not be transmitted by electricity—in a word, if what is spoken in Vienna may not be heard in Paris. The thing is practical in this way:

"We know that sounds are made by vibrations and are adapted to the ear by the same vibrations, which are reproduced by the intervening medium. But the intensity of the vibrations diminishes very rapidly with the distance: so that it is, even with the aid of speaking tubes and trumpets, impossible to exceed somewhat narrow limits. Suppose that a man speaks near a movable disc, sufficiently flexible to lose none of the vibrations of the voice, and that this disc makes and breaks the currents from a battery; you may have at a distance another disc, which will simultaneously execute the same vibrations."

This was a most remarkable prophecy, and it will be of interest to see how it came to be fulfilled. The name of the prophet was Charles Bourseul.

So far back as 1837 it had been observed that when an iron bar was magnetized and demagnetized rapidly it emitted a musical sound. This led to the invention of musical telephones, but the electric telephone capable of reproducing speech distinctly was not invented until 1876.

In 1874 Elisha Gray, of Chicago, had invented a

telephone, but it was used chiefly for transmitting telegraphic signals by means of musical sounds. It did not reproduce speech distinctly.

The speaking telephone was invented by Graham Bell, a Scotsman who had gone to reside in America. He desired to give a demonstration of his telephone at the Philadelphia Exhibition of 1876, but the committee did not include it as one of those to be demonstrated before a committee of experts. Bell was very much disappointed. While walking through the Exhibition he met the Emperor of Brazil, to whom he was known. In the course of conversation Bell told him of his great disappointment, whereupon the Emperor called upon those in authority and arranged that Bell would have an opportunity of demonstrating his invention.

When the appointed time arrived, the Emperor was present, and Bell invited him to be the first listener. Someone was stationed in a distant part of the Exhibition, and the telephone receiver was to reproduce the speech. When the Emperor put the telephone to his ear, he astonished the experts by exclaiming, "My God! it speaks!" Not only was he astonished, but such experts as Lord Kelvin (then Sir William Thomson) were astonished also.

Here is what Lord Kelvin said when speaking to a British audience about Graham Bell's telephone:

"This discovery, the wonder of wonders in electric telegraphy, is due to a young fellow-countryman of our own, Mr. Graham Bell, a native of Edinburgh and

now naturalized in New York. It is impossible not to admire the daring invention by which we have been able to realize with these simple expedients the complex problem of reproducing by electricity the tones and delicate articulations of voice and speech."

Bell's first telephone was what you might describe as two telephone receivers connected together, the one being used for speaking into and the other for listening.

Here is what the first telephone looked like (fig. 4).

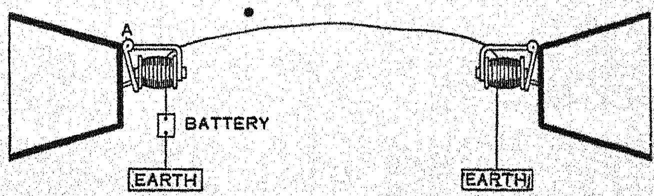


Fig. 4

The bobbin which you see in each instrument is an electro-magnet; but what is an electro-magnet?

When an electric current is passed through a wire surrounding an iron rod, the rod becomes a magnet. If you possess an electric battery, you can prove this by winding an insulated wire around the kitchen poker (fig. 5).

When a current of electricity is sent through the wire, the poker is able to support a key or other iron object. When you stop the current, the magnetism disappears, and the poker lets go its hold upon the

key. We can make the poker attract and let go at will.

With regard to the telephone, in front of one pole or end of the electro-magnet you see a little steel reed. This reed can move as a hinge at A, while the other end of the reed is connected to the centre of the diaphragm. In this early telephone the diaphragm was made of gold-beater's skin.

When the diaphragm was made to vibrate under

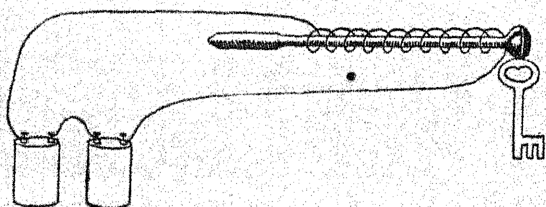
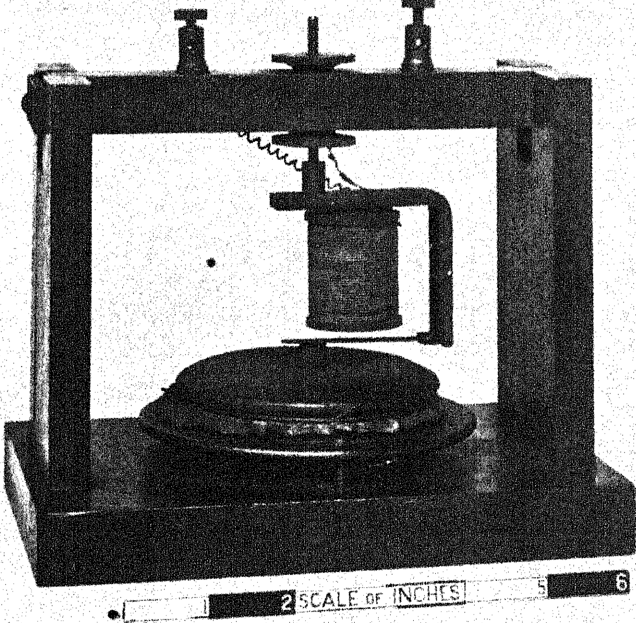


Fig. 5

the influence of the human voice, the little reed made similar vibrations in front of the electro-magnet. At this place there is what we call a magnetic field, an area containing magnetic force. When the steel reed moved in this field, it disturbed the electric current passing in the coil, and caused the particles of electricity to vibrate. This pulsating electric current arriving at the second instrument caused the magnet to pull and let go, and in this way it set the diaphragm vibrating in the same manner as the one in the other instrument. And so we have the speaker's voice controlling the first diaphragm, which controls the second



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BELL'S FIRST TELEPHONE (1875)

A membrane is stretched across the end of the mouthpiece, which is a tube opening into the base of the frame. The movement of the membrane due to the sound vibration controls the hinged armature below the electromagnet.

diaphragm, which sets up waves in the air just as the speaker is doing with his voice.

Two telephone receivers will act, over a moderate distance, without any battery at all. The mere movement of an iron diaphragm in close proximity to the electro-magnet will produce a flow of electricity in the coil of wire surrounding the magnet.

I have spoken from one room to another, using two telephone receivers without any battery. The one diaphragm imitates the other and reproduces the speech.

CHAPTER III

The Modern Telephone

In the modern telephone there are two distinct instruments, as in telegraphy, a transmitter and a receiver.

The receiver of to-day is very much like Graham Bell's original telephone, but the transmitter is on quite a different principle, though it serves the same purpose, viz. to control the outgoing current by the voice.

The accompanying drawing (fig. 6) will help you to understand how a modern telephone works.

We use a microphone as a transmitter; but what is a microphone?

Its simplest form is shown in fig. 7.

Its name is descriptive of its use. The word is derived from the Greek *mīkros*, meaning small, and you have already seen the Greek word *phōnē*, from which we get the phone of microphone, telephone, gramophone, and phonograph.

The microphone is a means of magnifying small sounds, and it does this so well that the footsteps of a fly walking across the wooden base of the instrument

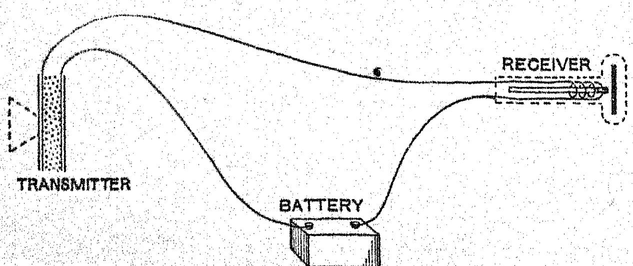


Fig. 6

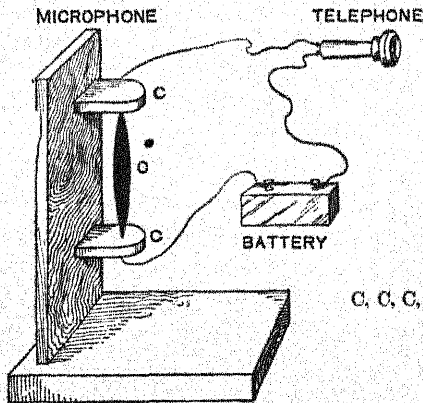
may be heard in a telephone receiver. The ticking of a watch sounds like the working of an engine.

In this microphone the electric current from a battery has to pass through a carbon pencil on its way to the telephone receiver. The pencil fits quite loosely between two blocks of carbon, one above and the other below it, as shown in fig. 7.

This loose contact causes a good deal of resistance to the passage of the electric current, but if the pencil is caused to vibrate it will permit the current

to pass more easily, and it will produce what we call a pulsating current. This current on reaching the receiver will cause it to work in a manner which will be described later.

The microphone of a modern telephone transmitter has a small box of powdered or granulated carbon in place of a carbon pencil, and the electric current



C, C, C, Carbon.

Fig. 7

finds difficulty in getting through this loosely packed material.

If we cause these particles to vibrate to and fro, they allow the current to pass more easily, and so again we get a pulsating electric current passing out to the receiver.

One side of the box containing the carbon forms a thin diaphragm, and it is against this we speak. The air-waves cause this diaphragm to vibrate in accord-

ance with the speech, so that an ever-varying electric current reaches the distant receiver.

This current passes through the coil of an electro-magnet, which you will see in fig. 8.

The iron diaphragm does not touch the magnet, but is placed close enough to be attracted by it and to be influenced by any change of magnetism.

The magnetism will vary according to the variations in the electric current coming from the transmitter, and this current is controlled by the diaphragm in that instrument. And so it comes about that the second diaphragm will imitate the movements of the first. In this way the diaphragm in the receiver produces waves in the air very like the air-waves which are moving the diaphragm in the transmitter. When the receiver is held close to the ear, these reproduced waves cause sensations of sound very like what the speaker makes at the distant end of the line.

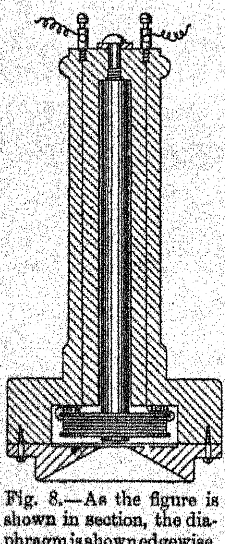


Fig. 8.—As the figure is shown in section, the diaphragm is shown edgewise. When facing the speaker it appears as a circular disc.

It has always seemed to me that the most marvellous part of the telephone is that a little flat disc of iron can imitate the human voice. In order to produce distinct words we have to use our lungs, vocal chords, tongue, mouth, nose, teeth, and lips. And yet a little

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AUTOMATIC TABLE TELEPHONE SET

iron plate can give such a good imitation of the same words that we have often no difficulty in recognizing the voice of a friend in the telephone.

Remember that the words spoken into a telephone transmitter do not leave the room in which they are spoken; the distant telephone receiver reproduces these sounds by means of the electric current, electro-magnet, and diaphragm.

The reproduction is so good that when an Indian heard a man's voice in the telephone for the first time, he stared at the instrument and said, "Heap little man!" thinking the man was inside it.

In the earlier days of telephony we had an electric battery beside each instrument, but now the electric current is supplied from the telephone exchanges.

We do not wish this current to pass through the telephone except when it is in use. We wish to cut off the connection with the battery when the telephone is out of use. That is what happens when the telephone receiver is hung up on the hook provided for it. The weight of the receiver depresses the hook, and this action breaks the connection with the battery. The drawbridge is taken up, and no current can pass to the line wire.

Then there is a bell to call attention when some one is desirous of speaking from the distant end.

In the earlier days the speaker had to ring the distant bell by turning a handle which drove a small dynamo, but to-day all this is done by the exchange.

I can remember when the telephones used to be

electrically connected to some water-pipe in the house or office, in order to get an earth connection, and save the double wire seen in fig. 6.

If both instruments were earthed, the telephone worked just as well as with a return wire, but there was one disadvantage. If the line wire happened to pass near another telephone wire, there was apt to be *cross-talk* between the two lines. The people listening on one line were apt to hear the message passing on the neighbouring line. We say that the one current induced a similar current in the neighbouring line. It was found that this trouble was not nearly so bad if a return wire were used, so the telephone of to-day has a complete metallic circuit in place of an earth circuit.

In the first days of telephony the instruments were connected in pairs, and communication could only take place between the two places at which the instruments were fitted up. At each end of the line there was both a transmitter and a receiver, so that a conversation could be carried on by both parties. But these two could only speak to one another, whereas you know that now we may speak to many different people. To enable you to do this is the purpose of a telephone exchange.

CHAPTER IV

A Telephone Exchange

Everyone knows how useful the telephone is to-day, and yet even intelligent people thought at first that it was merely a scientific toy. It was convenient to be able to speak to a friend at a distance; but it was a great advance in utility to be able to speak to any number of friends in different parts of the country. The speakers need not be in the same town, or even in the same country. A man in London may speak to a friend in Paris.

The part played by the telephone exchange is a very important one, and it will be of interest to see how it is that one telephone may be connected to any other one even in a different country. If we had only a dozen lines to deal with, we might bring all the ends of the twelve telephone lines into one room, and fasten or clamp them together at will; but, with several thousand lines to deal with, this simple plan is out of the question.

Nevertheless, we begin by gathering the whole crowd of telephone wires into one building. If the town or district is a very large one, we may require to give each area an exchange for itself; and in that case we have to give communication between these various exchanges. But how are the wires to be connected together? In fitting up houses with electric light it

is a common practice to leave the ends of wires fastened to sockets fixed in the wall, and into these wall-plugs may be fitted at will. In this way we can connect a reading lamp to the electric main, or we may connect with the main an electric iron or a heater.

The wall-plug consists of two little metal fingers, to each of which is fastened one of the ends of the wire from the lamp. The two little metal sockets are connected to the ends of the wires which lead to the electric power station. When the little metal fingers are pushed into the sockets, the lamp is connected through to the power station. The same idea is used for connecting telephone lines together, but the sockets and plugs must take up much less room than an ordinary wall connection.

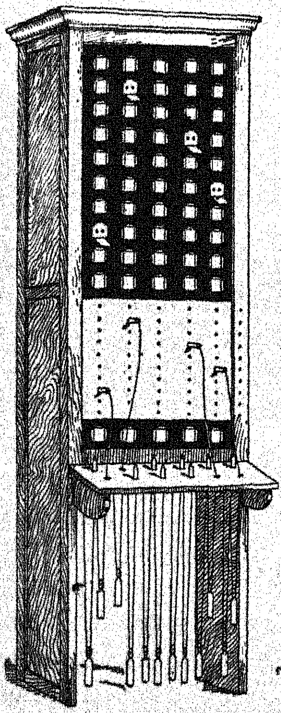


Fig. 9

In fig. 9 we see the plan upon which this is done. Each pair of wires is connected to a double socket which is called a "jack". You see the ends of these jacks exposed on the board which is called a switch-

board, because it is used for switching one telephone line on to another.

Fig. 10 shows how the wires from a telephone are fixed to one of these jacks.

One jack may be connected to another by using a short flexible cable containing two wires, with a plug on each end (see fig. 9). When these plugs are pushed into the jacks, they place the wires in con-

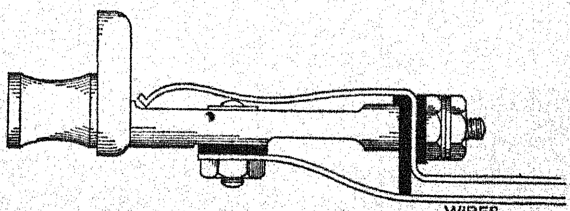


Fig. 10

nection with each other. The board in fig. 9 is for fifty telephone lines, and by means of these plugs any two of the fifty may be connected together.

In the drawing two pairs of telephones are connected. Others may be connected by using more plugs.

Having seen how one telephone line may be connected to another, it will be of interest to pay an imaginary visit to one of our large telephone exchanges. Some years ago it was very easy to recognize a telephone exchange from the great congregation of wires passing in through the roof of the building. But nowadays the telephone wires enter

the building from underground, and the lines all pass under the pavements in cables.

On entering a large room or hall we see a great many young ladies sitting round the room facing a long switch-board to which all the telephone lines are connected. The ladies are called operators, and each attends to the telephone calls of about fifty subscribers. We are surprised to hear how little noise there is. Each operator speaks quietly into her own telephone in reply to her subscribers.

Each telephone user is called a subscriber, because he subscribes a certain amount of money each year for the maintenance of the telephone exchange.

Many years ago the telephone subscriber had to turn a handle to ring the telephone bell of the subscriber to whom he was connected by the operator. He had to turn the same handle to call the attention of the operator when he desired to speak to her. I was surprised to find some people had the idea that they were ringing a bell at the exchange, and more than once I found someone turning the handle most vigorously, under the belief that he was making no end of a noise at the exchange, as he considered he was not getting proper attention. He was very much disappointed when I told him that all he was doing was to move a very tiny lever up and down on the switch-board, and that this movement could scarcely be heard.

If you look at fig. 9, you will see 50 little shutters which cover numbers representing the 50 subscribers.

When a subscriber turned the handle of his telephone ringing apparatus, the little shutter covering his number was released and fell down by gravity, thus exposing the number and informing the operator that No. so-and-so desired to speak to her.

The continual "ringing" only continued to move the little lever or catch which held the shutter up to cover the number. These were called indicators, but nowadays, when we wish to call the exchange, we merely lift our telephone receiver off its hook, and a small lamp lights up underneath our number on the switch-board and indicates the number calling.

When the operator, using a pair of plugs, connects us to the subscriber to whom we wish to speak, another little lamp, in connection with the plug, lights and remains lighted so long as you keep your telephone receiver off the hook. When the telephone receivers of both subscribers are replaced upon the hooks, this lamp goes out, and the operator knows that the conversation is finished.

Each operator has a portable telephone, the transmitter of which is carried by a little saddle arrangement on her shoulders and chest. The receiver is shaped like a watch and is carried by a band round her head, so that it is always at her ear. She has a short wire from her telephone with a plug, which she can place in the jack of the subscriber calling her.

The subscriber does not say "Please connect me with Mr. John Smith of such and such an address". He must look up the telephone directory and see what

number his friend is known by, and he then merely states the number of the subscriber to whom he desires to speak.

From fig. 9 we can see how it is possible for one operator to connect a subscriber to any one of 50 subscribers; but what if he asks for No. 1056?

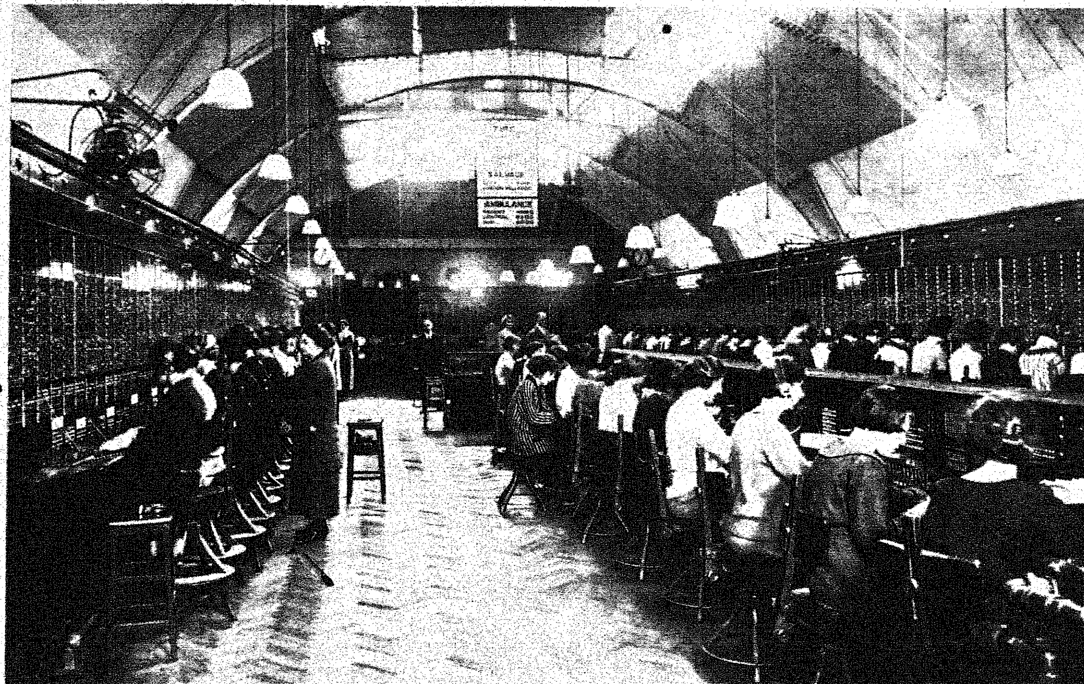
In a modern switch-board the jacks are made very much smaller than in fig. 9, and they are crowded close together.

Four operators together have in front of them the jacks of all subscribers connected to their exchange. The next four operators have a duplicate table, and these multiple tables are repeated right through the exchange, so that each operator can connect her subscribers' lines to any other lines.

When a subscriber asks for a certain number, it is evident that some other operator may have connected this number already to some other subscriber. What is to prevent several operators connecting up the same number at the one time and thus causing endless confusion?

This difficulty is overcome in a very ingenious manner. It is true that each subscriber has a separate jack in every table, but all his jacks are connected together by a wire in such a manner that, if any jack is in use, the operator in touching her jack for that number will hear a click in her telephone, and she is able to tell immediately that the line is engaged.

If a subscriber calls for a number which is connected to a different exchange, then the operator receiving



By permission of the Postmaster-General

GERRARD TELEPHONE EXCHANGE SWITCHROOM, LONDON

Compare this with the Automatic Exchange shown on the Plate facing page 33

the call calls up the other exchange on a connecting line called a junction line. Having told the other exchange the number of the subscriber wanted, she leaves the calling subscriber's line connected through to the other exchange, and the call is attended to in the way already described.

The same thing happens if a subscriber wishes to speak to someone in another town. The operator who answers the call switches the subscriber through to the exchange in the distant town. The lines connecting exchanges in different towns are called *trunk lines*. As already stated, the towns may be in different countries, but there is a limit to the distance if the towns are separated by sea. The telephone cannot be worked through a very long cable under the sea. We may speak through a cable under the English or Irish Channels, but it is impossible to speak through an Atlantic cable, though it is possible by wireless telephony to converse with America.

CHAPTER V

An Exchange without Operators

We have many clever automatic machines in our factories and workshops. These machines require only to be fed with materials, which they handle themselves without any further control.

One machine is fed with rods of brass, and it converts these into screw-nails. Another is fed with steel wire, which it makes into needles. Blocks of wood are fed into one machine, and they come out as matches, ready for use, and neatly packed in boxes.

A sewing machine is made by a number of automatic machines, and so are boots and shoes. Indeed, there are few industries in which automatic machines are not used. Nevertheless, it seems rather ridiculous to suggest that the operator in a telephone exchange may be replaced by an automatic machine.

Many years ago there was exhibited an alleged automatic machine which played a game of chess with a living opponent. This was considered a marvel until it was discovered that there was a living person hidden within the machine.

We have automatic telephone exchanges, and there are no young ladies hidden within the machines. Indeed, each machine is much smaller than an operator.

First of all let us see what happens at the subscriber's end of the wire. There is an ordinary tele-

phone instrument with the addition of a dial with numbers, as shown in fig. 11.

The disc, which is in front of the numbers, is capable of being turned round. When the subscriber desires to call, say, No. 2468, he puts his finger in No. 2 hole in this disc and pulls it round to the stop as though

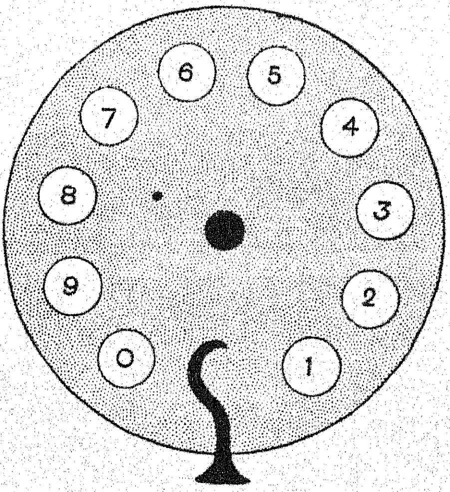


Fig. 11

he were putting the hand of a clock forward. Then he lets it spring back. Next he places his finger in No. 4 hole and repeats the operation, following with Nos. 6 and 8.

Having done this, he knows he is connected through to No. 2468. Let us now visit the automatic exchange and see what is happening there.

Instead of a busy hall filled with operators, we have

a number of queer-looking machines to which the wires are attached. Each of these is called a *selector*, because it selects the number required. There are a number of groups of selectors; it requires a group to find the number.

We watch the first selector at work. It has a

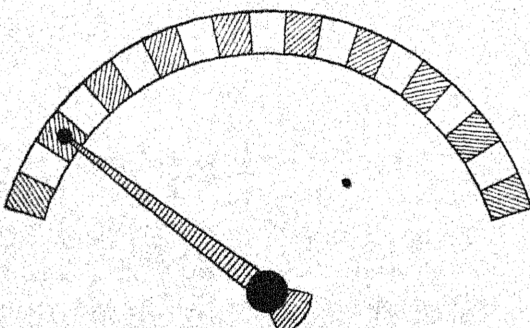
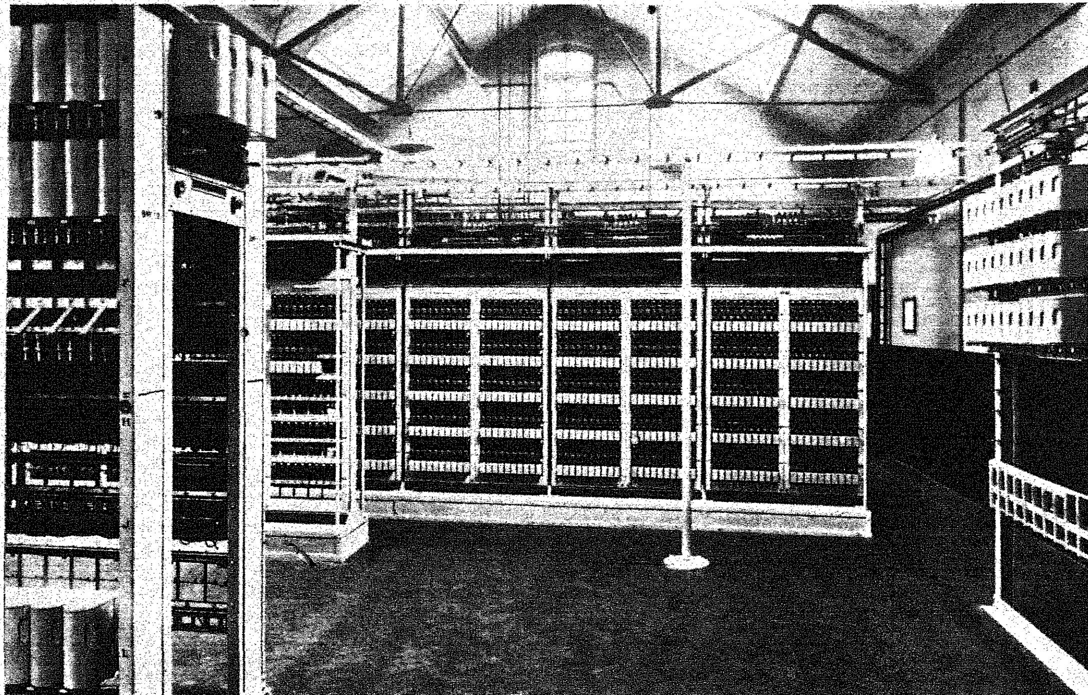


Fig. 12

pointer or lever as in drawing (fig. 12), in which you see 10 contact pieces. Each of these represents the end of a wire, and the little lever can turn round like the hand of a clock and touch each of these in succession. It is impulses coming in from the subscriber's instrument which cause this lever to turn. When the subscriber signalled the number 2, the lever received two impulses, which moved it to No. 2 contact and its connected wire. This selector in moving to No. 2 has switched the subscriber's line on to a wire leading to the selector which deals with the 2000 group of telephones. But where is the



By permission of Messrs. The Automatic Telephone Manufacturing Co., Ltd.

INTERIOR OF THE AUTOMATIC TELEPHONE EXCHANGE AT YORK

subscriber's telephone line? It is attached to the lever which moves round, and the lever has therefore placed the subscriber's line in connection with the 2000 group.

As the first operation acts on the thousands selector, all subscribers' numbers must have four digits, so what in an ordinary telephone would be No. 246 becomes No. 0246 in the automatic system.

The next signal sent is No. 4, and this selects the 400 group, so that the caller has got up to 2400; he still wishes to select 68. We watch the last selector, in which we may picture a semicircle with 10 contact pieces and immediately above that another 10, and so on until we have ten rows, representing the units, 10's, 20's, 30's, 40's, 50's, 60's, 70's, 80's, and 90's. The No. 6 signal arrives, and we see the little lever rise up to the sixth story. It has found the 60's, and at the next and last signal, No. 8, it turns round clock-wise eight steps, and now the subscriber is connected to the eighth line in the 60's of the 400 lot of the 2000 group. In other words, the calling subscriber is connected to the other subscriber whose number is 2468.

Before he sends his signals the calling subscriber lifts his telephone off the hook, and this automatically switches him to a selector which is free to attend him.

If he hears a droning hum in his receiver, repeated at regular intervals, he knows that the automaton has found the other subscriber's line to be already engaged. He hangs up his receiver and tries again

as soon as he thinks the other subscriber will be free.

When he succeeds in getting the number, there is an automaton which rings the other subscriber's bell until he lifts his telephone off the hook. Then the two lines remain connected until both subscribers hang up their telephones. As soon as this is done the selectors all move back to where they were before the call was given.

If we take a walk through the automatic exchange, we find hundreds of these little automatons packed close together in large cabinets. While we are standing opposite one cabinet, we see a red lamp light up over this particular group. The engineer is speaking with us and does not notice it till an alarm bell goes, and he then opens the cabinet, in which he finds one of the little levers has become fixed in its passage across the contact pieces. He frees it, whereupon it falls back to its stationary position, then it moves on to some number which a subscriber is calling.

If any selector fails to work, the red lamp lights up over the cabinet in which it is, and if not attended to in 30 seconds it rings an alarm bell.

These automatic exchanges were first used in America, but now there are a number of them in Great Britain.

It seems quite uncanny to see these little selectors working away with no one attending to them, but you know that the distant calling subscribers are sending impulses of electricity to them, and causing them to move as desired.

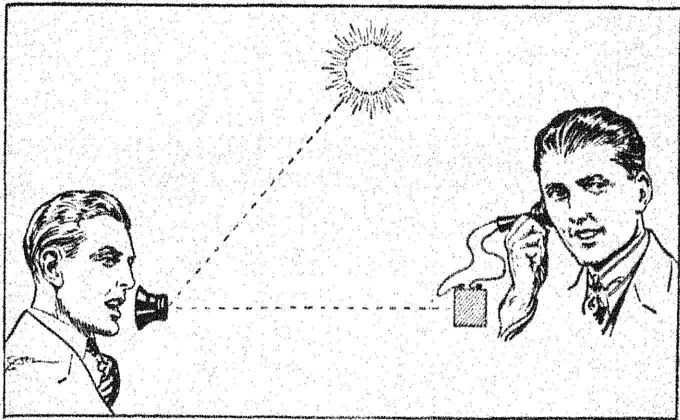


Fig. 13

CHAPTER VI

Speaking along a Beam of Light

It may seem ridiculous to say that we can speak along a beam of light. You did not think there was any connection between light and sound. You thought that *light* is waves in the ocean of æther, while *sound* is waves in the ocean of air.

These thoughts are quite correct. There is no direct connection between light and sound; but you will see what happens. The arrangement is as shown in fig. 13.

Boys sometimes play with a little mirror by which they can reflect a beam of sunlight in any desired direction.

Most of us have seen a great beam of light sent out by a powerful searchlight. The searchlight is merely a powerful electric lamp, with the light reflected by a concave mirror which focuses it and gathers it into a beam of light.

In the early experiments of speaking along a beam of light it was the rays of the sun which were used.

You see in the drawing (fig. 13) that a beam of light is reflected to the telephone receiver at some distance. The instruments had to have a clear path between them, as the æther-waves forming the beam of light travel in a straight line.

In this telephone experiment the light was reflected by a little flexible mirror. It was against the back of this mirror that the person spoke. The air-waves falling upon this flexible mirror caused it to vibrate, and its vibrations sent impulses through the æther-waves of light. These impulses were controlled by the human voice, and when they arrived at the distant station they controlled a telephone. How was this accomplished?

Light could not operate a telephone, so it was made to control an electric current which could operate it. The next thing we wish to know is how light is able to control an electric current.

There is a simple or elementary substance which is called *selenium*. Its name is derived from the Greek *selēnē*, the moon. Selenium is not a metal, but is of a nature not unlike sulphur. What interests us at

present is that it has a very strange property. When it is in the dark, it offers considerable resistance to the passage of an electric current through it. We say it is a poor conductor. But strange to say, when light falls upon it, the resistance is so decreased that the current of electricity can pass. It acts just like a water or gas valve in controlling what passes. The more light that falls upon the selenium, the more electricity does it allow to pass.

It is in this way that light is made to control the current passing from the electric battery to the telephone in the experiment which we are considering at present.

The electric current will vary according to the pulsations of light falling upon it. We have seen already that the beam of light will vary with the speech, and therefore the electric current will do the same. This varying current will operate the telephone, and will cause its diaphragm to vibrate in sympathy with the little mirror which forms the diaphragm in the transmitting apparatus. Just as in the ordinary telephone, this special telephone will reproduce the speech.

It is interesting to note that this is really wireless telephony, and that it was accomplished in 1878, which was sixteen years before the invention of practical wireless telegraphy by Marconi.

This experiment of speaking along a beam of light has been put to a practical use in America, where the experiments were made.

This system of telephony has been used for com-

municating between ferry boats and the shore. A powerful electric arc lamp was used as the source of light, and a beam from this was focused on to the little mirror which forms the speaking diaphragm. The beam from this mirror was directed to the distant ferry boat, where it affected a selenium cell which controlled the electric current passing to the telephone receiver.

It will be apparent that there will be a limit to the possible distance over which this system can be used, but a conversation by such means has been carried on successfully over a distance of some miles.

It is interesting to note that the most recent development in wireless work is the use of a beam of waves, directed in the desired direction.

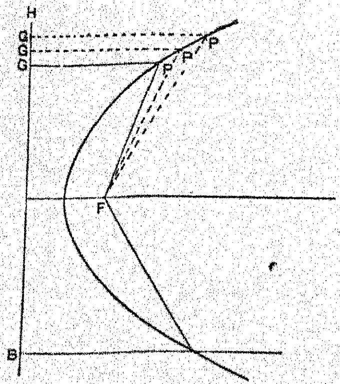


Fig. 14.—A Parabola. The curve is traced out by the point P which moves in such a way that its distance PF from the focus F is always equal to its perpendicular distance PG from a fixed straight line HB called the 'directrix'.

The waves which constitute light are the very same as those which carry our wireless messages, only the electric waves used in wireless are very much farther apart. We call these *longer* waves, and some of them measure several miles between crest and crest.

It is difficult to reflect such long waves, and those which are reflected for wireless are called

shorter waves, but they are still very much longer than the waves which form light.

In the early days Marconi used metal mirrors to reflect the wireless waves, but now the reflector is made of a series of wires forming what we call a parabola (fig. 14), or what you might describe as an egg-shape.

The idea in using a beam of wireless waves is the same as that in the experiment described in this chapter. But there is a difference in the results obtainable. A beam of light can only be used when the objects are not very far distant, or we might say only as long as the two stations are within sight of each other. We may send a beam of wireless waves right from here to Australia, as these waves bend round the earth.

CHAPTER VII

A Telephone with a Good Memory

It might seem a jest to say that there is such a thing as a telephone with a good memory, and yet there is a machine which will accept a message in its master's absence, and repeat it to him on his return.

This machine is called a *telegraphone*. You can see this word is derived from the Greek *tēle*, at a distance, *graphō*, I write, and *phōnē*, a sound. It writes sound at a distance. It has been called also a

telephonograph, which is merely the word telegraphone turned round another way.

It has been named also a *magnetophonograph*, and this name tells you that magnetism plays an important part in the work done by the instrument.

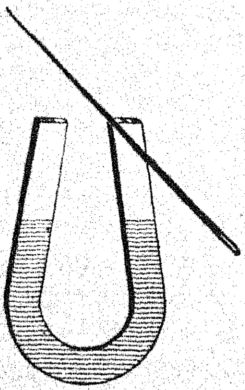


Fig. 15

It will be well to consider one or two points in connection with magnetism, as they play an active part in the making of the record of the sounds spoken into the machine.

If you draw a magnet along a piece of steel wire, you will magnetize the wire. Many boys and girls have made knitting needles and sewing needles into magnets by stroking them with a magnet (fig. 15).

You may use a permanent steel magnet or one of those temporary magnets which we describe as electro-magnets, because they are only magnets so long as a flow of electricity is passing through a coil of wire around the iron core (fig. 16).

Suppose you had a steel wire passing under the pole of an electro-magnet. The steel would only become magnetized so long as you kept passing an electric current through the magnet's coil. You could produce spots of magnetization by starting and stopping the current.

That is what happens in the telegraphone, in which

the human voice controls the current passing to the magnet.

You know how the little magnet in a telephone receiver attracts and lets go an iron diaphragm, causing it to vibrate in sympathy with the distant voice. The duty of the electro-magnet in the telegraphone is to produce spots of magnetization in the

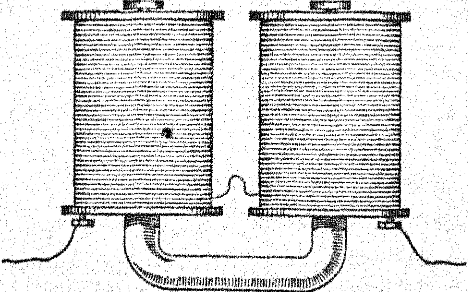


Fig. 16

wire passing against it, and these are controlled by the voice.

Having taken a magnetic record of the telephone message by means of this magnetophonograph, as it is sometimes called, we then pass the wire against the electro-magnet of a telephone receiver. What will happen? We have seen elsewhere that a magnet in motion produces an electric current, and changes of magnetism produce a similar electric current. The moving magnetized wire alters the magnetism in the electro-magnet, and this produces an electric current

which is capable of operating an ordinary telephone receiver.

In this way the record, taken down by the telegraphone on the magnetized wire, causes a telephone receiver to imitate the speaking diaphragm, and the telephone message given to the telegraphone is repeated at will. 12,920

Let us take a look at the instrument. In one form of it we see a steel tape passing under the poles of an electro-magnet, and a gentleman is dictating some letters to the machine instead of to a shorthand writer. We see that the wire is gradually passing from a full reel to an empty one. Its speed of travel is about seven feet per second, which is somewhat quicker than the pace of a smart walk.

When dictating the letters, the speaker may desire to alter something he has said. He touches a button, which causes the machine to stop and run the wire backwards. The wire passes under the poles of a permanent magnet which obliterates or wipes out the magnetism from the wire, just as you can take a piece of rubber and rub out what you have written in error.

This permanent magnet serves a second purpose. It is in action also when the wire is travelling forwards, but in that case it acts before the wire reaches the recording electro-magnet, and this serves a useful purpose. The owner does not wish to use a new reel of wire for every lot of letters. He may use a reel of wire for a second lot of letters, and this

permanent magnet obliterates the old record before it reaches the electro-magnet.

When the speaker has finished his dictation, he lays down the telephone transmitter into which he has been speaking, and this action causes an indicator to show in the typist's room. The typist puts on a pair of head telephones such as used in wireless, and these are connected to the telegraphone. She moves a switch which sets the telegraphone in motion, and as the wire passes in front of the electro-magnet in the machine, the speech is repeated. The typist need not take this down in shorthand, because the machine will go at a rate which she can follow on her typewriter. If she should fail to catch all that it says, she moves another switch, whereupon the wire goes back a little and repeats what it has already said.

The permanent magnet is withdrawn from the wire while the machine is speaking to the typist, otherwise the message would be obliterated before it reached the electro-magnet. It is only when the machine is being spoken to that the permanent magnet clears the wire for receiving the fresh speech.

The reels with the wire are driven by a small motor, which may be electric or clockwork as in a gramophone.

If the typist has occasion to stop the machine while she is typing the letters, it will move the wire backward a little way, so that it gives her the end of the last sentence over again before it goes on with the fresh dictation. This arrangement is a

great convenience to the typist, for the machine is in another room, standing on the dictator's desk. It is under her control so long as it is being used by her. Only the head telephones and the switches are in her room.

The inventor has provided means of taking a record suitable for sending by post. In this case the machine makes the magnetic record on a flat steel disc, not unlike a gramophone record, both sides of which may be used. Such records may be used in place of written letters, provided both the sender and the receiver possess a telegraphone.

The inventor of this machine was a Dane. His name is Valdemar Poulsen, and he is known, by those who are well versed in wireless, as the inventor of a speaking-electric-arc. Poulsen invented the telegraphone in Denmark in the beginning of the present century.

At first he made it very like a phonograph, for the wire was wound in a long spiral around a cylinder, which was turned round as in a phonograph, but afterwards he made the wire travel from one reel to another as already described.

CHAPTER VIII

The Optophone

The Optophone is seen in the plate facing page 48, and even if you failed to notice that the man is blind, you might guess from the name of the machine that it has something to do with seeing and sound.

You will recognize the first part of the word *optophone* as being related to the word optician, whom you know to be one who sells spectacles, telescopes, microscopes, and opera glasses. These instruments are for seeing with; the name optician is derived from *optos*, seen.

In the optophone one may be said to see by means of sound, for a light showing upon the printed type of a book causes sounds in a telephone receiver, and these sounds may be recognized as coming from the different letters in the alphabet.

After having read the chapter on speaking along a beam of light, you will be able to guess that selenium will play a part in the making of the optophone, for it enables light to control a telephone.

It will be of interest to examine the optophone and then, in fancy, to listen to it. We see an open book lying face downwards on a glass plate which is supported on a suitable stand.

This book-rest consists of a metal frame standing on four feet and supporting a curved sheet of glass

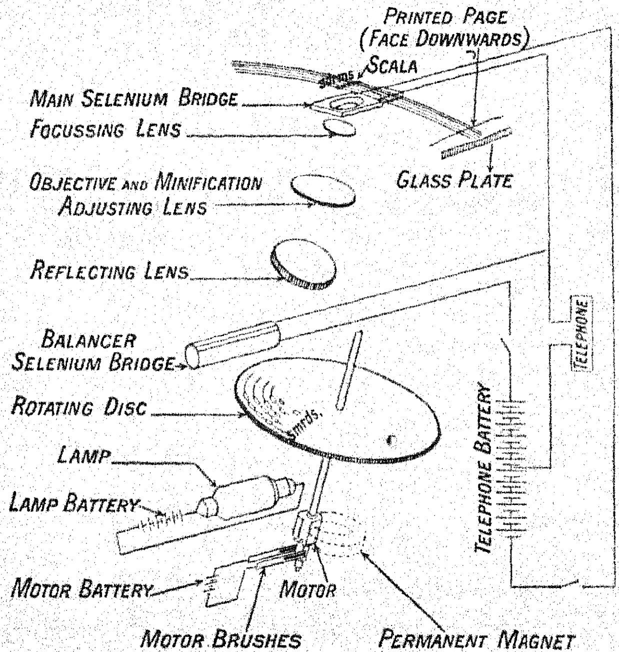


Fig. 17.—Diagrammatic arrangement of Optophone

upon which the book rests. Means are provided for clamping down the page so that it lies in close contact with the upper surface of the glass.

You could guess that there is sure to be a lamp in the machine for producing a beam of light. We see a little lamp with a filament stretching straight across the glass tube. This lamp is covered by a porcelain plate, in which there is a small hole to permit a beam of light to pass out and fall upon the printed page. This light will be reflected back from the page to the

porcelain cover, which is prepared as a sensitive selenium bridge and is connected to a battery and head telephone.

We see that the beam of light, after being reflected from the page, passes through some holes in a black disc (fig. 18).

This reminds one of the discs used in a siren. If

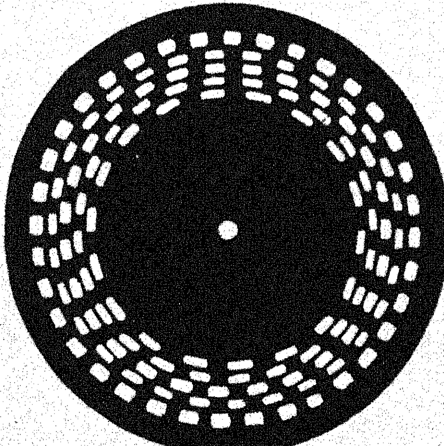


Fig. 18

you have never seen a siren, you are almost sure to have heard one. It makes a loud noise, while its notes rise and fall in the scale.

You could almost tell, without any explanation, how it works. It will produce air-waves according to the rate at which the air passes through the succeeding holes while it is revolved past a jet of air. This rate

will depend upon the number of holes we cut in the plate, and also the speed with which we make the holes pass the jet of air. The faster it goes, the higher will be the note.

Occasionally one hears a siren, fitted to a bicycle wheel, giving warning to pedestrians. In the optophone this plate or disc with the holes is not to permit sound to pass, but to control the light reflected from

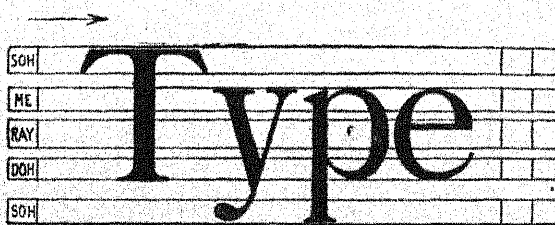
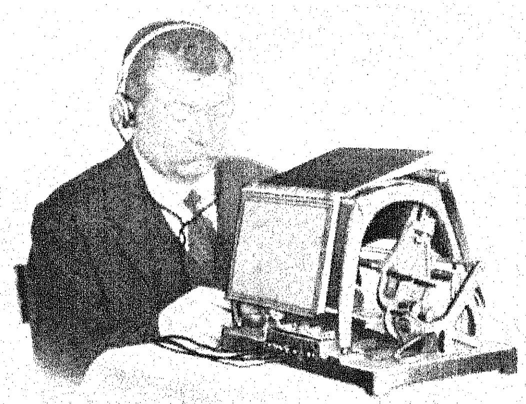


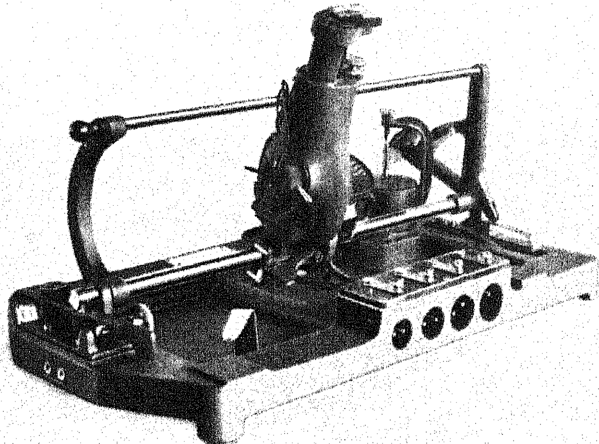
Fig. 19

the printed type. It will make no noise, but the interrupted light will affect the selenium bridge, and this will control the electric current passing to the head telephones, in which sound will be produced.

When the light passes through the outer row of holes, there will be more interruptions to the light than when it passes through the inner row of holes, because there are more holes in the outer row.

If we put on the head telephones and listen to light passing through each row of holes in succession, we hear the notes soh, doh, ray, me, soh. If we alter the speed of the little motor which is driving the disc, we merely alter the key; we still have soh, doh, ray, me, soh.





By permission of Messrs. Barr & Stroud, Ltd.

THE OPTOPHONE

In the top picture a blind reader is using the instrument. Below is shown the Optophone with the book rest removed.

Suppose the beam of light to be reflected by the printed word "Type" as shown in fig. 19.

You see that the top part of the capital letter will reflect the light.

In reality it is the plain page which reflects the light and the black letters absorb it, but the machine causes the results to be reversed. This reversal is brought about by using a second beam of light upon a second selenium bridge, but we need not trouble with this. It is sufficient for our purpose to know that the beam of light falling upon the top part of the capital "T" produces soh in the telephone.

It will be seen from fig. 19 that the long ends of the letters "y" and "p" pronounce the soh which is an octave lower. The intermediate notes me, ray, doh, are produced by the main body of the type. We make the light pass over a capital "V", and as it passes the first downward stroke we hear soh, me, ray, doh, and as it passes the upward stroke we hear ray, me, soh. The sound in the telephone runs down and then up the scale, or "scala" as it is called in the optophone.

We make a small "v" pass, and we can easily distinguish it from the capital, for it only sounds me, ray, doh, ray, me.

When the light passes over the small letter "o", it sounds ray, then a cord of me and doh together, then it finishes off with ray, thus ray, $\frac{\text{me}}{\text{doh}}$, ray. Each letter produces a definite series of sounds,

which can very easily be recognized with a little practice. At first the reading will be very slow, and even after practice it cannot be very fast; but think of the great advantages.

Imagine some good fairy telling a blind man that she would make him read ordinary books instead of the raised type to which he has become accustomed. She would indeed be counted a good fairy. The optophone is such a fairy. It enables the blind to read any book of ordinary print.

Some books are printed in much larger type than others, but the light can easily be focused by the blind man when listening in the telephone. He can adjust it to cover the capital letters.

If we take another look at the instrument, we will see that the little lamp, with its disc and selenium bridges, travels along the line of print on a shaft. When the lamp has reached the end of one line, the shaft moves it down to the next line, and so on it goes till it reaches the bottom of a page, when it can be placed opposite the first line of the next page.

The blind operator can make the machine go as fast or as slow as he or she wishes. The speed is regulated by merely turning a screw.

The optophone was invented by Dr. E. E. Fournier d'Albe, of London, and it has been greatly improved by Messrs. Barr and Stroud, Limited, Glasgow, who are making it. The one disappointment is that it costs about one hundred pounds to make each instrument.

CHAPTER IX

Applications of the Telephone

The telephone may be used as a loud speaker. A demonstration of this was given in America in 1912. Loud speakers were fitted up in the large halls of an Exhibition at Boston, and were used to make announcements to the public, and also to distribute music from gramophones.

One incident showed a practical use of these loud speakers. A child, having been separated from its parents in the crowd, was taken to a position of safety, and an announcement of this fact was made immediately throughout the great building by means of these loud speakers. This enabled the parents to know at once that their child was safe and where the child was.

At this Exhibition there were 90 loud speakers fitted throughout the large buildings, and these were all connected to one transmitting telephone placed in a sound-proof telephone cabinet.

I have seen these loud speakers used at sports to make announcements of the different events about to take place, and to tell the results of the various contests. The instruments were placed around the sports ground so that the members of a vast audience of 100,000 people could all hear distinctly. The speaker was at one end of the grounds, and the speaker's unaided voice could not have been heard

excepting by those in his immediate neighbourhood.

On one occasion a distinguished politician was using loud speakers to address some 50,000 people gathered together in the open air. He held the transmitting telephone in his hand, and his voice was heard by all. During his address he wished the chairman to coach him on one particular point, and he spoke in a whisper, forgetting the tell-tale instrument in his hand. His whisper was heard by the whole audience, which was evident by the sudden roar of laughter.

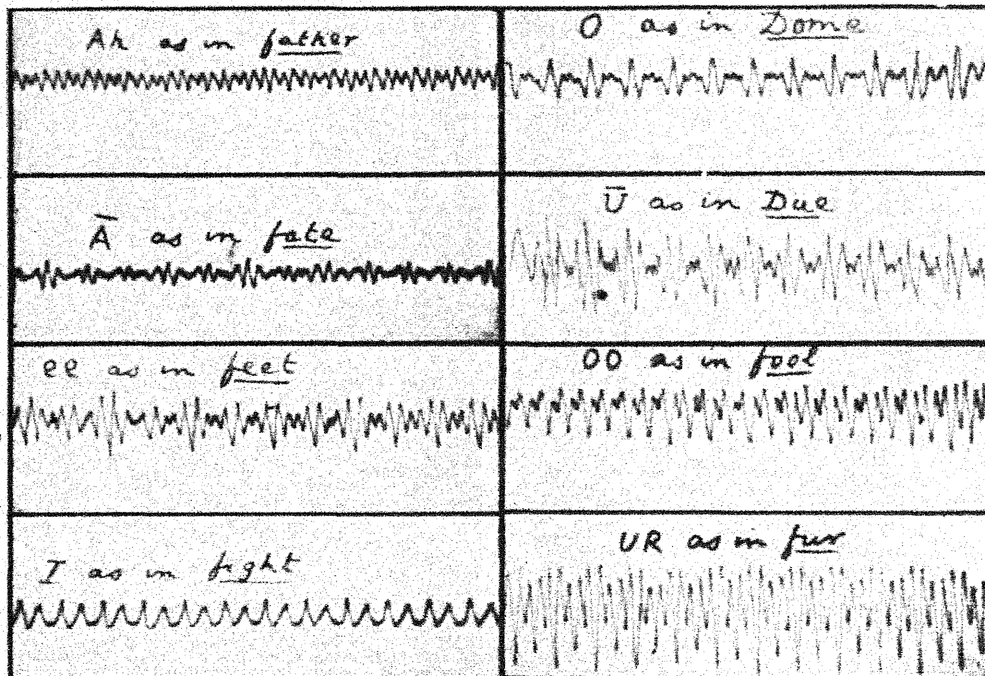
There is another invention in which the voice is recorded and reproduced on a principle entirely different from the telegraphone. This instrument was called originally a photographophone, but more recently a photophone.

The first name was more descriptive, as photography plays an important part in the recording of the sounds. From what has been said in some of the other chapters, you will be able to guess that selenium takes part in this invention. How did the invention come about?

In 1900 W. Duddell gave a demonstration of what he called a musical arc. You may have seen an electric arc lamp lighting up a street or railway station, though those arc lamps are not so much in use as they were some years ago.

The electric current passes between two carbon pencils and produces a very bright arc of light. Duddell used one of these lamps in his demonstration.

I saw this demonstration repeated in the University of Glasgow by my old friend Professor M'Kendrick,



CURVES REPRESENTING THE WAVE FORM OF CERTAIN VOWEL SOUNDS

Photographed on Kinema films by the Fleming Photoscope. Reproduced from *Fifty Years of Electricity*, by courtesy of Dr. J. A. Fleming.

and it may be of interest to see what occurred on that occasion. First of all there was shown an arc lamp on the lecture table connected up to a telephone transmitter, so that the electric current passed through the telephone and also through the arc from the one carbon pencil to the other.

A whistle was played in front of the telephone, whereupon the arc lamp began to jump and give forth the same notes. At that time it was called by some a "whistling arc".

The human voice was shown to affect the arc also. Then the telephone was taken to another part of the building out of earshot. One of the assistants, going to the distant end, sang into the telephone. The professor told us what was going to happen at the distant end, and we heard the song coming from the arc on the lecture table.

The assistant then spoke into the distant telephone and the arc repeated the words, but at that time speech was not produced distinctly.

With improvements made later, speech was so well reproduced that the arc was renamed the "speaking arc". It was this which suggested to Ernest Ruhmer, of Berlin, the idea of his photographophone, which he invented in 1901.

Ruhmer's idea was to photograph the varying light from the speaking arc, and then use the record to reproduce the sound when desired. What he did was to take a cinematograph picture of the light coming from the varying arc. Imagine the arc flickering

like a dying candle. The flickerings of the arc are not so pronounced, but they are there, and they are controlled by the voice speaking into the telephone.

In the cinematograph a series of thousands of pictures are taken in quick succession. The light in this case forms actual pictures, whereas in the recording of sound there are merely bands of different shades of light. Nevertheless, we have made a record of the behaviour of the arc, which varied in accordance with the music or speech. The record on the photographic film is not much to look at, but it is marvellous how it can reproduce the sounds. It is here that the selenium comes again to our aid.

The film is passed between a lamp and the selenium, so that the beam of light falls upon the selenium after passing through the film. In this way the light is varied, just as it was in the speaking arc. This ever-varying beam of light acts upon the selenium, in the manner described in another chapter, causing more or less electric current to pass to a telephone receiver or to a loud speaker. The variations in the electric current operate the telephone diaphragm in the usual way, and the sound-waves are reproduced.

The distinctness of the reproduced sound is remarkable, and the loudness may be increased by using a more powerful source of light to act more vigorously upon the selenium. The inventor points out that one advantage in his system is that he can reproduce any number of records by merely printing

from a negative in the usual method adopted in photography.

Ruhmer suggests that his instrument might be used in conjunction with the ordinary picture cinematograph, so that the actors in the pictures could speak to the audience by means of loud speakers.

Perfect timing of the speech and actions could be obtained by taking both records—the scene and the sound—on the same film.

Many years ago I put a telephone to do curious work. It so happened that the nursery in my mother's house was on the top floor and the servants' quarters were on the ground floor. On one occasion a baby girl was a visitor in the house, and her mother was distressed at the distance between the nursery and where her nurse might be spending the evening. The child might cry and the nurse could not hope to hear her.

To get over this difficulty I placed a telephone transmitter near the child's cot, and connected this to what I called an electric balance, which was placed in the servants' quarters.

Here is a drawing of the general arrangement of the apparatus (fig. 20). You see the two wires leading from the electro-magnet (A). These go to the distant telephone transmitter.

When the child cried, the sound controlled a constant electric current which was maintained in the telephone line.

In order to get a good electric current I used what

was called a bichromate battery, in which the zincs stood in acid, being lifted out, under ordinary circumstances, when the battery was not in use. My battery had to be ready to act at any moment, so there was nothing for it but to leave the zincs continually in the acid. I can remember that it

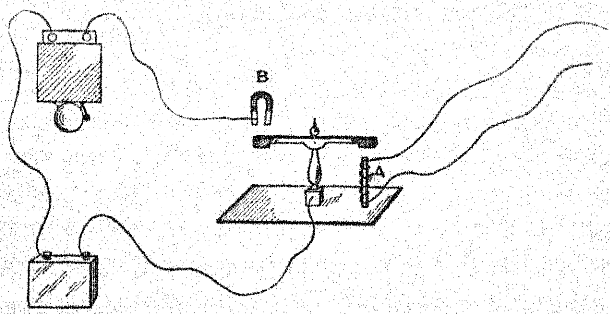


Fig. 20

cost quite a lot of pocket-money to keep that hungry battery supplied with zincs.

When the electric current in the telephone was varied by the child's cries, the electro-magnet (A) of the receiving instrument did not act upon a diaphragm, but upset the balance of a small lever, one end of which moved towards the electro-magnet while the other end moved towards a permanent magnet (B), which laid hold of the iron lever and held it to it.

If you look at the drawing, you will see that this gave the battery current a passage through the

balance to the permanent magnet (B) and thence to an electric bell.

The bell continued to ring until the nurse disconnected the lever from the permanent magnet. After trying this I found that the apparatus was too delicate for everyday use, and I used an ordinary telephone receiver, which if laid near the nurse enabled her to hear when the child cried.

This experiment was made before the invention of the loud speaker, or I would have had no difficulty in giving the nurse better warning of the cries.

I published an account of the experiment in one of the scientific journals, and some years later an American writer, coming across the article, wrote a description of it as though it were an invention that was widely used in this country; it was merely an experiment.

CHAPTER X

A Speaking Machine

About 1880 the newspapers announced that a speaking machine had reached Paris, and it attracted a good deal of attention. It was not shown, at first, as a scientific thing, but merely as a curiosity.

Some people said it was trickery and that the speaking was done by a ventriloquist. A ventriloquist is one who can speak in such a manner that the voice appears

to come from a doll, or from within a box, or from behind a door, or elsewhere.

This suggestion was very hurtful to the exhibition of the speaking machine, which was a genuine automaton. The idea was to make a machine which would imitate the means of producing human speech. Human speech is a complex thing, and the machine which was made to produce an imitation speech was necessarily very complex.

Such an attempt had been made as early as the thirteenth century. It was called a speaking head, and it was destroyed as being a work of the devil.

The speaking machine which was shown in Paris in 1880 consisted of three distinct parts:

(1) There was an attempt to imitate the lungs, by using a bellows for producing currents of air, as we do when speaking. This bellows was worked by a pedal.

(2) Then there was a vocal box, or *larynx*, with diaphragms of various forms. These were to control the air and make the sound. There was a mouth, rubber lips and tongue, and a short tube to represent the nostrils.

(3) There was a set of levers terminating in keys, as in a piano.

The most interesting part of the machine is shown in fig. 21.

This is the part for producing the sound, which we know is composed of air-waves.

A large rubber tube formed the windpipe of the automaton. A blast of air from the bellows set an

ivory diaphragm vibrating, and this produced the necessary sound. The force of this sound was controlled by the keys. The force depended upon the opening made in a slit through which the air passed. This slit part represented the *vocal chords.*

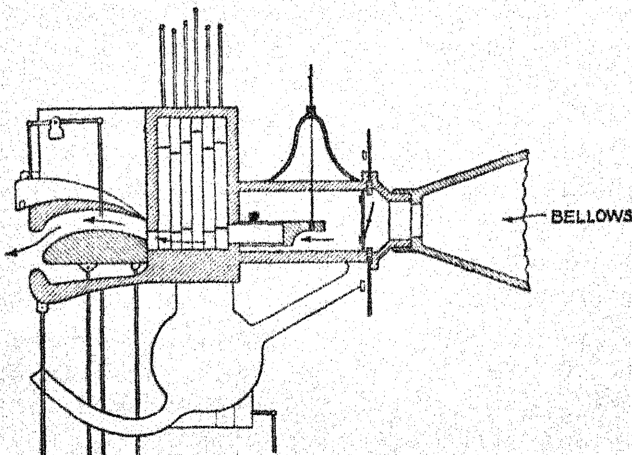


Fig. 21

A circular piece of metal was placed above the upper lip of the machine. This plate had a small hole in it, and the result of passing air through this made a sound not unlike the pronunciation of the letter "F".

The depression of other keys produced sounds like a, o, u, c, e, l, r, v, s, ch, b, d, g.

Words were composed by combining different keys, and these were quite distinct, but were spoken in a monotonous and drawling tone.

Those who suggested that the speaking was done by a ventriloquist supposed that this drawling was done on purpose to make people think the machine was speaking.

One who saw this machine has said:

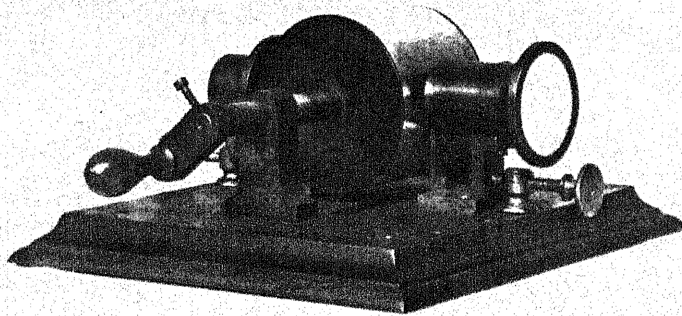
"As for the mechanical execution, it is impossible to admire too highly the simple and ingenious manner in which all the complicated movements of the different vocal organs have been connected with the keyboard, of which the mechanism has been so calculated as only to produce the precise action of the organ which is required for any given effect. . . . The public will believe that the assertions of ventriloquism are unfounded when I add that I myself have made the machine speak."

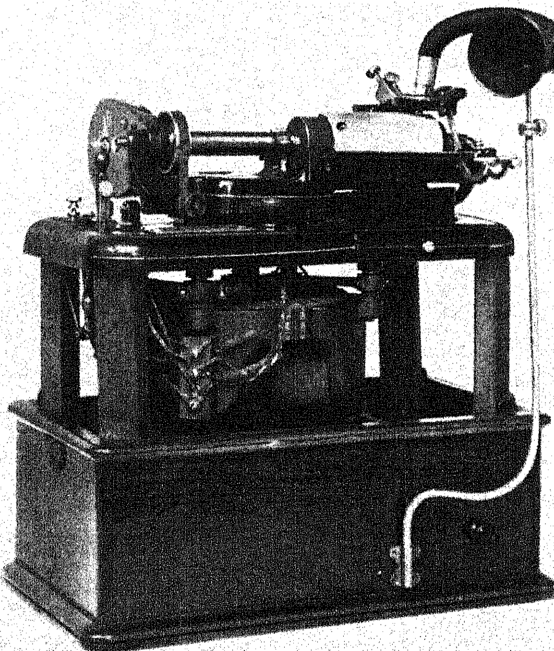
Referring again to the telephone, the present writer will never cease to marvel at the fact that the little diaphragm of a telephone receiver is able to do far better than this complicated speaking machine.

There are a few limitations to the performance of the diaphragm, but we are so accustomed to the use of the telephone that we fill these in unconsciously.

One difficulty that the diaphragm has is in reproducing the sound of the letter "S". The same thing happens in an echo; it gives the "S" as a "V". Hence the story of the sacred echo in France. When one shouted "Satan" (which is pronounced Sa-tong in French), the echo replied "Va-t'en" (Va-tong), which is the French for "Go away!"

It is curious that the telephone diaphragm confuses





By permission of the Director of the Science Museum, South Kensington

EARLY FORMS OF PHONOGRAPHS

Above is shown Edison's Original Tin-foil Phonograph. Below a Wax-cylinder Phonograph made by the Edison Bell Company in 1904.

the sounds of "Two" and "Three". One would not expect this, and when I observed it many years ago I spoke to the manager of a telephone exchange concerning it, but he said he had never noticed it.

I had records kept at three different telephones of numbers called and numbers given in error for these. It was surprising how often the error was between 2 and 3.

I consulted a friend who is a great authority on sound, and he could not explain it. I spoke also to a friend who is a well-known psychologist (one who studies the mind), and he could not understand the confusion. Not being able to get anyone to sympathize with my quest, I allowed the matter to drop, though I was still convinced that the confusion did exist. Some years later I was travelling to London, and I happened to be examining some coloured photographs which were then very uncommon. A gentleman sitting opposite asked if he might see these, as he was interested in the subject of colour. This led us to discuss some points in connection with colour vision. After this we had both been reading for some time when this stranger said to me: "I wonder if you could explain a difficulty to me. How is it that 2 and 3 get confused on the telephone?"

It was a very strange incident. I had been trying to convince people of this confusion, but they were doubtful, and after I had abandoned the subject an entire stranger put the same question to me, and that without any previous mention of telephones.

CHAPTER XI

What led to the Invention of the Phonograph

A great invention need not be anything original. We have a very clever weaving machine called a Jacquard, and it is named after its inventor. It is a curious fact that Jacquard really invented nothing new. In his day there were two weaving machines for producing figured cloth, but neither of them was very satisfactory. In these machines cards passed over a wooden cylinder and controlled some needles, which in turn controlled the threads in the loom. One of the machines had a good arrangement of cylinder but an unsatisfactory arrangement of needles. The other had an unsatisfactory cylinder and a good needle arrangement. All that Jacquard did was to take the good cylinder from the one machine and unite it to the good needle arrangement of the other. He invented nothing new, but by combining these two parts he made a machine so satisfactory in its working that it has been used for more than a hundred years with practically no alteration. It is seldom that an invention does not contain something new, but there is always something existing previously which has led the inventor to his idea. There were steam-engines in use before James Watt invented the steam-engine of to-day.

What, then, led up to the invention of the phonograph?

You will recognize this word as being composed of one half of the word tele*phone* and one half of the word tele*graph*, and you will remember that the Greek word *phōnē* means sound, while *graphō* means to write. It is clear that a phonograph is an instrument to do with the writing of sound.

This word phonograph has been replaced by the word gramophone, which is practically the same word turned the other way about. You recognize the *gram* as in telegram.

Long before the invention of the phonograph, scientists had sought to record speech, but with no intention of reproducing it. Their idea was to make speech record itself, so that they might study these records and learn as much as possible of the nature of sounds.

In 1855 Mr. Leo Scott invented an instrument for this purpose, and gave it a long name which was descriptive of its work. It was called a phonautograph. Every boy and girl knows what an autograph is, and it is self-evident that the word *phonautograph* means the autograph of sound. The Greek word *phōnē* has become quite familiar to us, and we know that it means sound.

Scott made his machine on the model of the human ear. He had a funnel or horn for collecting the sound, and the sound-waves fell upon a drum-skin or membrane which was stretched across the narrow end of the horn just as in the ear.

In the ear we have a small chain of bones connected to the drum-skin, so that the vibrations, produced in this membrane by the sound-waves, are conducted to the inner ear and the sensations are telegraphed to the brain.

In the phonautograph there was attached to the back of the drum a flexible bristle. The free end of this rested upon a lamp-blackened sheet of paper. When the drum vibrated, the end of the bristle moved from side to side, and traced its movement on the blackened surface. The blackened paper was fixed

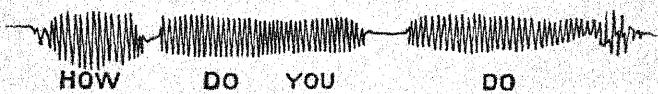


Fig. 22

around a cylinder which not only revolved, but also moved along so that the point of the bristle would trace a spiral line around it.

When anyone spoke into the horn, the movements of the bristle were traced upon the blackened paper. It was made possible to compare different sounds by comparing the tracings which the bristle made.

Fig. 22 shows what the tracings were like. The sounds were made to write their autographs.

It was the phonautograph which gave Edison the idea of recording speech in the phonograph. I think that the reproduction was suggested to Edison by the invention of the telephone. We have seen in

one of these chapters how the telephone reproduces the spoken words by means of a vibrating disc or diaphragm.

We have marvelled that a little flat disc is able to imitate the voice so well, and far better than a complicated speaking machine.

In the telephone receiver the diaphragm is made of iron, because it has to be acted upon by a magnet; but as this is not the case in the phonograph, its disc may be made of a sheet of mica or glass, or any other stiff material of light weight.

In Edison's first phonograph he attached a metal needle to the diaphragm, and when it vibrated it pressed against a sheet of soft tin-foil which was stretched over a large brass cylinder. There was a deep groove around this cylinder, and this groove formed a spiral in which the point of the needle moved.

Instead of making marks on a blackened surface, as the bristle of the phonautograph did, this needle made indentations in the soft tin-foil.

I have seen Edison's original phonograph. It was a very large affair which required several men to lift it. The cylinder was revolved upon a shaft which had a heavy fly-wheel on one end, and on the other end there was a crank for turning by hand.

The cylinder was turned as steadily as possible while words were spoken into the horn. The cylinder was moved along by means of a spiral screw-thread on the shaft, just as in the phonautograph.

After the record was made on the tin-foil, the

cylinder was moved back to the beginning of the spiral and the needle was placed at the beginning of the long line of indentations.

The crank was turned again, and the needle, moving out and in of the indentations, caused the diaphragm to vibrate just as it had done when spoken against, and the words were reproduced as in a telephone receiver.

If you could hear this first phonograph speak, you would consider it a very poor affair. To-day it would be a very bad phonograph, but it was the first, and all our gramophones of to-day are descended from it.

Edison would admit that it was a very poor reproduction of speech, and could not compare with the telephone of Graham Bell. Nevertheless, it showed the way in which speech could be reproduced. Edison invented this machine in 1877, and it was shown in exhibitions in America and in Paris. It was looked upon as a curiosity.

You may wonder that Edison made no improvement in his phonograph for the next eleven years. No doubt the reason was that he was very busy trying to invent some means of using electricity for lighting houses. This was of much more importance than a talking machine.

In 1888 he made a decided improvement by discarding the heavy brass cylinder with its soft tin-foil covering, and using in its place a cylinder of soft wax. The vibrating needle made much better indenta-

tions on this wax cylinder than was possible on the sheet of tin-foil.

He also introduced a clock-spring to drive this new cylinder, and we shall see in the next chapter how this led on to the modern gramophone.

CHAPTER XII

The Gramophone

After Edison made his phonograph with a wax cylinder and a clockwork driver, it proved a great success. Cylinders were sold with records of music played by orchestras. There were violin, banjo, and cornet solos, and many songs by eminent singers.

People marvelled how the records of such things could be sold so cheaply, as there was no means of making one record from another. Each record had to be made in the phonograph.

One day I received an invitation to see a record being made, but on condition that I did not publish anything about it at that time, as the process was secret. The secret was that dozens of records were taken at the one time in the following manner.

In the centre of a room there was a large funnel hanging down from the ceiling. A record was going to be taken of a cornet solo, and the player stood underneath this funnel. Flexible tubes led from this

funnel to a crowd of phonographs situated round the room. The sound operated the diaphragms and cutting needles of each of these, so that each machine made a separate record.

In those days one heard at the end of each record the applause of the audience, and it was believed generally that the record had been taken before a large audience. One could even hear some members of the audience shouting "Encore".

On the occasion of my visit I was surprised to find that the audience consisted of a few operators who were in the room, and I was asked to join these and to make as much noise as I could at the end of the music. As soon as the music ceased, we gathered under the funnel and shouted while we applauded, some using sticks upon the floor. It was this which gave the hearer of the record the idea of a vast audience.

At the commencement of each of the records in those days there were a few words stating that the record had been made by the Edison Bell Company, and this led to the following incident.

I was letting a boy of three years of age hear a phonograph for the first time. In putting on the first record I omitted the introductory speech by accident. The boy was greatly pleased with the music.

On putting on the second record it announced that it was an Edison Bell record, whereupon my little friend fled from the room, and nothing would persuade him

to return. All he said was, "Man speaked". This was bad grammar, but it let me see that the little fellow considered the talking machine to be an uncanny thing. Indeed, it is possible that he believed a man to be hidden within the small box.

When M. Puskas, acting for Mr. Edison, showed the phonograph to the Academy of Science in Paris, 1878, some people imagined the speech to be produced by trickery, just as was said of the speaking machine described in a former chapter.

Here is an extract from a French newspaper of those days:

"A report soon ran through the room which seemed to accuse the Academy of having been mystified by a clever ventriloquist. One said that the sounds emitted by the instrument were precisely those of a ventriloquist. Another asked if the movements of M. Puskas's face and lips as he turned the instrument did not resemble the grimaces of a ventriloquist. A third admitted that the phonograph might emit sounds, but believed that it was much helped by the manipulator. Finally the Academy requested M. de Moncel to try the experiment, and as he was not accustomed to speak into the instrument (i.e. to make a record), it was unsuccessful, to the great joy of the incredulous. Some members of the Academy, however, desiring to ascertain the real nature of the effects, begged M. Puskas to repeat the experiments before them in the secretary's office under such conditions as they should lay down. M. Puskas complied with this request,

and they were absolutely satisfied with the result. Yet others remained incredulous, and it was necessary that they should make the experiment for themselves before they accepted the fact that speech could be reproduced in so simple a way."

The phonograph had a wax cylinder, whereas the

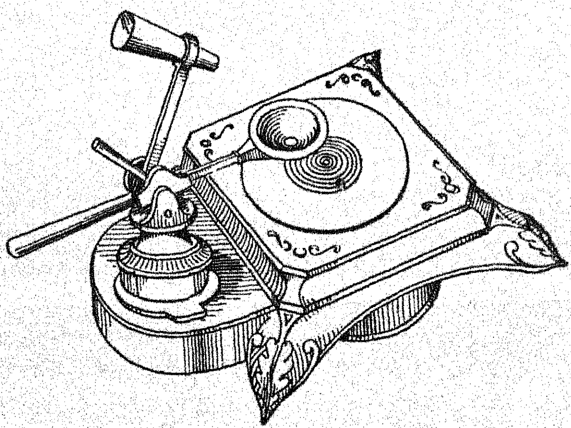


Fig. 23

gramophone has the record on a flat disc; and some people imagine that this constitutes the difference between a phonograph and a gramophone. That is not the case. How do I know?

Because among the descriptions of early phonographs I have found some illustrations showing some of the instruments with flat discs. Edison even tried this plan while he was working with tin-foil records. Here is a reproduction of the illustration (fig. 23).

The word gramophone is merely a newer name for a phonograph.

Fig. 24 shows the construction of the human ear, and it is really remarkable how similar is the construction of the sound-box of the gramophone.

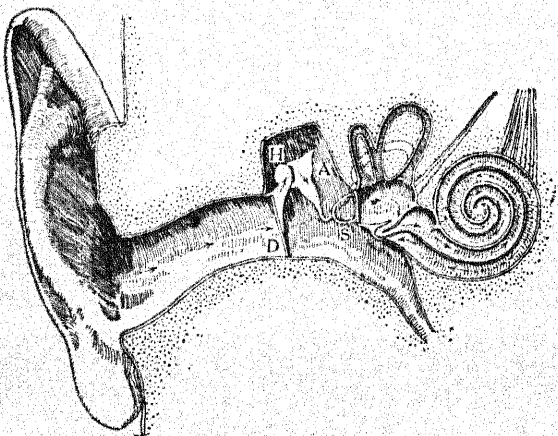


Fig. 24.—Section of the Ear. D, Drum; H, Hammer; A, Anvil; S, Stirrup.

The gramophone is used to such a large extent in reproducing the sound on fixed records that one does not think so much of the process of the recording of the sound on the record. It is in doing this that the sound-box of the gramophone resembles the ear.

It will be of interest to make a comparison of the gramophone and the human ear. The horn of the ear is not so noticeable as that of the gramophone. The horn of the ear is called the *outer ear*, and is that

part which you see. Behind this is the *middle ear*, and farther in is the *inner ear*.

You know how it aids hearing to use an ear trumpet or horn. I have seen a deaf person using a horn much larger than an ordinary gramophone horn. It was about four feet long, and so large that

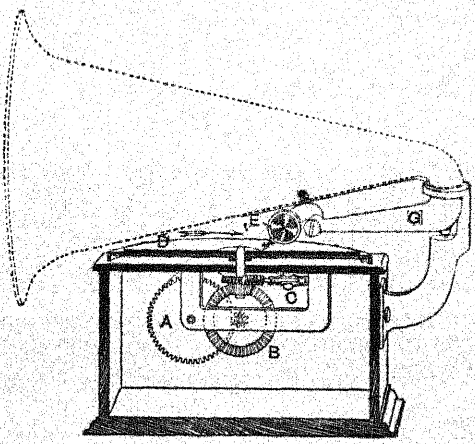


Fig. 25

it required to be supported on a stand as in the case of a large camera.

Instead of speaking into the outer ear, the operator speaks into the gramophone horn, and the sound-waves produced by the voice fall upon a diaphragm made of some hard material, instead of falling upon the drum or *tympanum* of the ear. This diaphragm divides the outer from the middle ear, in which there is a little chain of three bones, one of which is

fastened to the tympanum. These conduct the vibrations to the inner ear.

In the gramophone we have the needle fixed to the diaphragm conducting the vibrations to the recording disc.

In the inner ear we have the vibrations converted into sensations.

In the gramophone we have the movements of the needle converted into marks upon the disc.

If you have handled these gramophone discs, you may have wondered how it was possible to make the records on such a hard substance. The records are not made directly on to those hard discs, but upon softer material, and the hard records are made from that, using it at first as a mould. Any desired number of duplicates can be made from the original record.

Consider the construction of the gramophone as shown in fig. 25. The machine requires some energy to make it go, and you supply that energy when you wind up the clock-spring which is hidden in the base of the instrument. You store the energy in this spring, and it is allowed to uncoil itself very gradually, and in doing so it turns the cylinder A in which the spring is contained. A toothed wheel, called a ratchet, works into a pinion wheel and conveys this turning motion to a large bevel wheel B. You can see a pinion wheel fitting into the wheel on B and carrying with it a short upright shaft which in turning round will revolve the turn-table along with it. This gives the necessary motion to the record.

As the record turns round, the needle or *stylus* fits into the grooves on the record which represent the vibrations. These form a long spiral line which gradually guides the stylus from the edge of the disc towards its centre.

The stylus carries with it the sound-box, which is shown in the drawing at E.

Here is an enlarged drawing of this sound-box and stylus with a part cut away to show where it fits on to the horn (fig. 26).

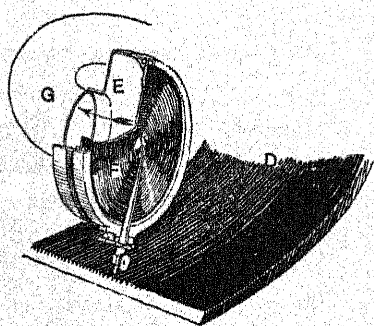


Fig. 26. — D, Disc; E, Sound-box; F, Diaphragm; G, Tone arm

C represents the governors, which keep the clockwork motor going at a steady pace. You know how the speed can be regulated. The faster you make it go, the higher is the pitch of the sound.

As in the case of the telephone, the most marvellous part of the gramophone is that the little diaphragm can imitate the human voice.

QUESTIONS

CHAPTER I

1. What is the derivation of the word *telephone*? (Note that in phone both o and e are long.)
2. State briefly what sound is.
3. What produces the sound in (1) the piano, (2) violin, (3) trumpet?
4. Why is it colder on the top of a high mountain than in the valley?
5. Describe the kind of waves which produce loudness.
6. How are the sizes of the waves altered?
7. Describe long and short waves, and state how they are produced.
8. How often do the wires producing the middle C of the piano vibrate in each second?

CHAPTER II

1. Describe the string telephone, and state how it works.
2. What may be used in place of the string?
3. In the electric telephone what is it that travels?
4. Who prophesied the telephone twenty years before it was invented?
5. Who invented a telephone for telegraphic purposes?
6. In what year and by whom was the speaking telephone invented?

7. Where was it first shown?
8. What great scientist was present at the demonstration, and what did he say about it?
9. How could you make an electro-magnet?
10. Describe how the telephone acts.

CHAPTER III

1. Make a simple drawing showing how a telephone transmitter is connected to a distant receiver.
2. Describe a simple microphone, and state what it does.
3. What is the derivation of the word microphone?
4. Describe the microphone in a modern telephone.
5. Make a drawing of a telephone receiver, and state how it works.
6. What is the most marvellous thing about the telephone?
7. Where is the battery of a modern telephone placed?
8. How is the electric current cut off when the telephone is not in use?
9. How did early subscribers call the exchange?
10. How is cross-talk minimized?

CHAPTER IV

1. Why do we have telephone exchanges?
2. How are the wires connected at the exchange?
3. What is a "jack"?
4. How does the operator know who is calling her?
5. How are the wires led into a telephone exchange nowadays?
6. Why are people called telephone subscribers?
7. How does the operator know when the subscribers have finished speaking to one another?

8. What kind of telephone does the operator have?
9. Why do the subscribers get numbers?
10. What prevents an operator connecting more than two subscribers together by mistake?
11. What is the name given to the lines connecting different towns together?

CHAPTER V

1. Mention some of the things automatic machines can do.
2. What is the difference between an ordinary telephone exchange and an automatic one?
3. Describe how a subscriber gives a call on the automatic system.
4. State very briefly what happens at the exchange.
5. What is the name given to the automaton at the exchange, and why is it so called?
6. How does the subscriber learn that the line he wishes is engaged?
7. How is the other subscriber told he is wanted?
8. What happens when both subscribers put their telephones back on the hooks?
9. Where did automatic exchanges originate?

CHAPTER VI

1. Why might it seem ridiculous to talk of speaking along a beam of light?
2. Draw a diagram showing how we can speak along a beam of light. Omit the persons using the instruments.
3. What is a searchlight?
4. What substance is used in the receiving instrument? Describe how it acts under the influence of light.
5. What causes the light to vary?
6. In what year was this experiment first tried?

7. Where has this system been put to practical use, and for what purpose?
8. What is the difference between wireless waves and visible light?
9. State a recent development of wireless telegraphy in this connection.

CHAPTER VII

1. Name the telephone instrument that has a good memory, and state why it is so named.
2. Mention other two names given to it.
3. How can you magnetize a knitting needle?
4. Describe an electro-magnet.
5. In the telephone with a good memory, what is it that records the message?
6. State one purpose to which this instrument is put.
7. How is any error erased?
8. Explain how the typist receives the message dictated.
9. In what form can messages be sent by post?
10. Tell what you know of the inventor of the telegraphone.

CHAPTER VIII

1. What is an optophone?
2. Mention another word derived from the same source.
3. What substance plays an important part in the making of the optophone?
4. How are the notes produced?
5. Describe briefly how any letter is heard.
6. How many musical notes are used?
7. Who invented the optophone?
8. Name the Glasgow firm which has greatly improved it.

CHAPTER IX

1. When and where was the demonstration of a telephone used as a loud speaker first given?
2. Give an account of an event which proved the loud speaker of practical use.
3. How many people has it been possible to address at one time with the aid of loud speakers?
4. Explain briefly what a photophone is, and mention another name which describes it better.
5. State briefly how the invention came about.
6. Mention some other names given to the musical arc.
7. To what purpose may the photophone be put at some future date?
8. Explain what the "baby alarm" did, and state very briefly how it worked.

CHAPTER X

1. What kind of trickery did people suspect in connection with the speaking machine when shown in Paris?
2. Explain how ventriloquism might have accounted for the speaking of the machine.
3. State briefly how the machine worked.
4. What letter of the alphabet does the telephone find it difficult to say?
5. Tell the story of the sacred echo of France.
6. What two numbers did the author find to be confused on the telephone?
7. What curious confirmation had the author regarding this telephone confusion?

CHAPTER XI

1. What did Jacquard do, and was his invention useful?
2. From what Greek words was the word phonograph derive
   and how was the word gramophone suggested?
3. What two instruments suggested the invention of the phon
   graph, and who invented it?
4. Explain the derivation of the word phonautograph.
5. Of what is the telephone diaphragm in the receiver mad
   and why?
6. On what material were the first phonograph records taken
7. In what year was the first phonograph invented, and h
   long did it wait for any real improvement?
8. Mention two outstanding improvements.

CHAPTER XII

1. Describe the taking of an early phonograph record.
2. Explain how the applause at the end of the record w
   produced.
3. Relate the incident of a small boy and his first hearing of t
   phonograph.
4. Why was the child frightened?
5. When the phonograph was first shown in Paris, what d
   some people suspect?
6. Are the phonograph and the gramophone different inventio
7. Tell what the gramophone sound-box is likened to, a
   mention what parts are similar.
8. How are the gramophone discs made?
9. Give a brief description of how a gramophone works.